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Salvage of the Failed Total Wrist Arthroplasty: A Systematic Review

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Abstract

Background Although the performance of total wrist arthroplasty systems has improved, failure is encountered and is a major challenge to manage.

Questions Does physical function improve with surgical management of the failed wrist arthroplasty? Is there an improvement in secondary outcome measures including pain, grip strength, and range of motion? What are the reasons for failure in primary total wrist arthroplasty? What are the complications associated with revision of the failed total wrist arthroplasty? What are the survival profiles of the different revision strategies?

Methods A systematic review of available literature was performed. Studies were systematically assessed, and data extracted from suitable studies for review. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines were adhered to. The study protocol was modified from a previous protocol published on the PROSPERO database.

Results Fourteen studies were identified considering 218 patients/214 index operations with a follow-up duration following revision surgery of 2 months to 21 years (silicone wrist arthroplasty—42 cases; nonsilicone wrist arthroplasty—172 cases). The functional outcome of revision surgery was infrequently recorded and documented with only short-term assessments undertaken. Complications were seen in 1:2 revision procedures, with re-revision surgeries required in 21.6% of revised primary nonsilicone arthroplasties. Re-revision rate following a revision arthrodesis was 21.4% (15/70 cases) compared with revision arthroplasty of 34.8% (32/92 cases). Revision arthrodesis nonunion rate was 17.5% (22 cases).

Conclusion This review has confirmed the high level of surgical complexity and the likelihood of a complicated postoperative outcome when salvaging a failed wrist replacement.

Level of Evidence This is a Level 3, systematic review study.

Keywords
- wrist arthroplasty
- revision
- systematic review

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Total wrist arthroplasty (TWA) prostheses have undergone continued evolution since the first implant designs in the 1960s. The first widely-used implant was the Swanson silicone prosthesis (Wright Medical Technology, Arlington, TN), introduced in 1967.[1] Although good initial pain relief and functional motion, longer followed-up revealed implant failure rates of up to 65%.[2–4] Since then, there have been many developments in wrist replacement design, culminating in the current fourth generation implants. These newer implants require less bone resection and the stems tend to be porous-coated to enable osseointegration.[5,6]

Despite the continued evolution of these implants and improvements in survival rates, failure of TWA continues to be encountered and presents a major challenge to the treating surgeon.[7] Conversion to total wrist arthrodesis is the most common solution but, in some cases, revision to a new arthroplasty can be considered. Excision arthroplasty is also used in some scenarios.

There are only a few articles reporting on the outcomes of treatment or "salvage" of a failed TWA.[8–21] The aim of this study is to undertake a systematic review of the available literature to assess the clinical effectiveness of the different strategies that can be utilized in this challenging situation. The following research questions forming the basis for this review are: Does physical function improve with surgical management of the failed wrist arthroplasty? Is there an improvement in secondary outcome measures including pain, grip strength and range of motion? What are the reasons for failure in primary TWA? What are the complications associated with revision of the failed TWA? What are the survival profiles of the different revision strategies?

Methods

A study protocol was created prior to undertaking this systematic review. This study protocol was based on a predefined protocol registered on PROSPERO from a previous study (Prospero CRD42017067377).[7] The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were adhered to in performing and reporting this study.

Inclusion and Exclusion Criteria

Studies were included if participants were adults over the age of 16. The underlying clinical diagnosis was arthritis of the wrist of any type. The main intervention type was revision of a failed TWA. The studies included were at a minimum "case series"/level IV evidence.

Exclusion criteria included patients having undergone partial wrist replacement procedures and failure to report on any of the primary or secondary outcomes. No minimum duration of follow-up was set. Only studies published in the English language were reviewed. Animal or cadaveric studies were excluded.

The types of outcome measures were based on the recommendations from OMERACT (Outcome Measures in Rheumatoid Arthritis Clinical Trials) for both rheumatoid arthritis and osteoarthritis.[22,23] The primary outcome was physical function and the secondary outcome measures were pain, grip strength, range of motion, adverse events, and survival of the revision procedure. Failure of the revision procedure was defined as failure requiring removal of one or both components of the implant or a nonunion in revision arthrodesis cases. Major surgical revision was defined as revision arthroplasty (one or both components), revision to arthrodesis, revision arthrodesis for nonunion, or resection arthroplasty.

Search Strategy

The following databases where searched: OVID Medline & Embase, Cochrane CENTRAL, CINAHL, and BNI. ClinicalTrials.gov and the WHO Clinical trials portal were also searched. Finally, the NICE database was also searched. The primary search date for all the above was chosen as June 2, 2017. A final update search was performed on January 20, 2018. The "PICOS" elements were used to construct an effective search strategy. The search strategies are provided in ►**Appendices 1 to 4**.

Data Collection and Analysis

The basic dataset was adapted from the Cochrane Handbook for Systematic Review of Interventions.[24] Additional data were included: cause for failure of the primary arthroplasty, the type of revision procedure, and whether re-revision occurred. The results of the literature search are summarized in ►**Fig. 1**.

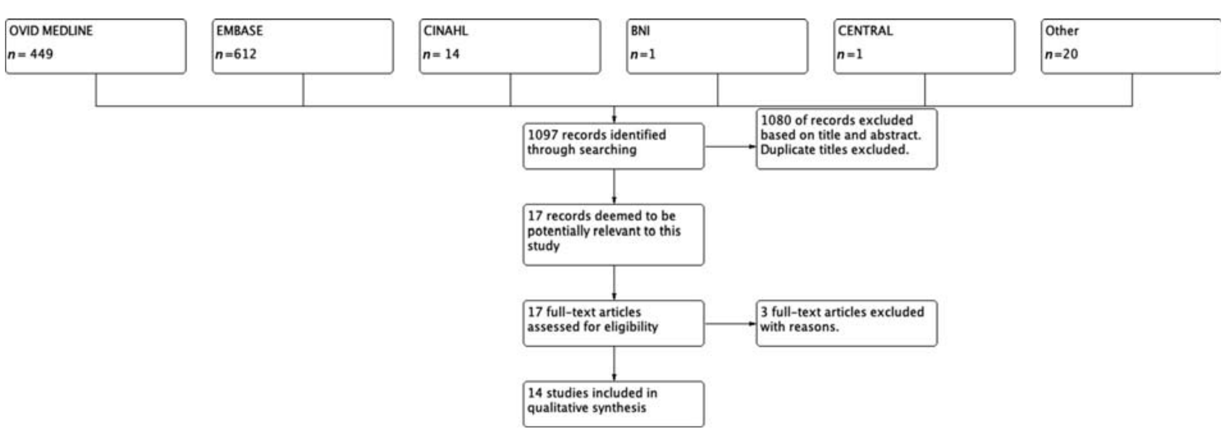

Fig. 1 Summary of the study selection process according to PRISMA guidelines. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Table 1 Patient demographics

	Revision cases
Total number of patients	218
Total index operations	214
Male:Female	1:5.5
Average age	58.9 y
Underlying primary pathology	
Inflammatory arthritis	*88.1%*
Rheumatoid arthritis	83.8%
Psoriatic arthritis	2.5%
Juvenile idiopathic	1.9%
Non-Inflammatory	*11.9%*
Post-traumatic arthritis	5.6%
SNAC	3.8%
Kienbock's disease	1.3%
SLAC	0.6%
Degenerative arthritis	0.6%

Abbreviations: SNAC, scaphoid non-union advanced collapse; SLAC, scapholunate advanced collapse.

Results

The 14 studies identified in this systematic review represent 218 patients undergoing 214 revision procedures for failed TWA spanning a period from 1976 to 2018.[8–21] ►**Table 1** summarizes the demographic data from these studies. The studies were retrospective in nature apart from Cobb and Beckenbaugh and Reigstad et al.[11,19] Average follow-up ranged from 2 months to 21 years. The underlying primary pathology was predominantly rheumatoid arthritis and females were more frequently affected.

A summary of the 14 studies is provided in ►**Table 2** including details of the primary procedure and details of the revision methodology. In general, the procedures could be divided into revision total arthrodesis (91 cases), revision arthroplasty (113 cases), excision arthroplasty, or insertion of an antibiotic impregnated spacer for infection. The arthrodesis was commonly performed using tricortical iliac crest bone graft or femoral head allograft. Two studies described contouring a femoral head allograft to match the carpal defect.[17,18] A variety of techniques were employed to stabilize the interposed bone graft, including a Steinmann or Rush pin, often with supplementary Kirschner wires or staples,[9,12–14,16,17] a dorsal locking plate,[13,16–19,21] or an external fixator.[8,17] Reigstad et al also described the conversion of a stable Motec wrist arthroplasty to an arthrodesis by replacing the ball and socket components of the replacement with a custom made peg.[19] Major surgical revision was required in 214 of the 218 cases (►**Fig. 2**). The remaining revision cases were managed with soft tissue reconstructions only.[8,9,15] A revision arthroplasty procedure was chosen as the salvage operation in 53% of the cases (92 of 172 cases) involving a failed nonsilicone total wrist replacement. The remaining cases were managed with conversion to a total wrist arthrodesis (41%; 70 of 172 cases) or were treated for infection. Infection was the underlying cause for revision in 11 cases. These were managed with either an excisional arthroplasty (four cases),[8,13,16] revision with an antibiotic cement spacer followed by staged fusion (six cases),[8,9,19] or early debridement and retention of the implant in one case.[8]

A summary of the different arthroplasty systems across the 14 studies is given in ►**Table 3**. The Biaxial total wrist arthroplasty (DePuy, Warsaw, IN) and the Universal 2 (Integra Lifesciences, Plainsboro, NJ) were the most common implants chosen to salvage the failing TWA. Cobb and Beckenbaugh described use of a long-stemmed revision version of the Biaxial with optional multipronged distal components.[11] Similarly, Lorei et al described the use of a custom Trispherical wrist implant for revision.[13]

Three articles were excluded including one by Reigstad et al[25] as more recent data was reported by Registad et al,[19] and in a further two studies which failed to report on any of the primary or secondary outcomes listed in this review.[26,27]

What Are the Reasons for Failure in Primary Total Wrist Arthroplasty?

The underlying reason for failure has been summarized in ►**Table 4**. This was difficult to ascertain in some of the studies as either limited or no information was provided. This summary is therefore not comprehensive and should be used as a guide. As some of the studies were historical, revision of the Swanson silicone prosthesis was also described. Silicone fracture was given as the sole cause of failure of the Swanson silicone arthroplasty in 23 of the 37 implanted cases. Loosening of the distal component was the most common cause of failure for the other arthroplasty systems. However, there was one described incident of loosening as the mode of failure in a Swanson silicone arthroplasty case.[14]

Pain (without other obvious abnormality) was the underlying reason for revision in 18 cases. Despite this, pain was a common associated feature and indicator for revision in a large number of cases. In the study by Adams et al for example, pain was the primary complaint in all patients, but failure was attributed to a variety of different reasons including loosening, recurrent dislocation, and implant fracture.[18]

Soft tissue complications such as attritional tendon ruptures were common especially in earlier studies.[8,15] Two studies of note reported on the fate of the Meuli wrist arthroplasty and in both a high incidence of soft tissue complications was observed.[8,15]

Does Physical Function Improve with Surgical Management of the Failed Wrist Arthroplasty?

The functional outcomes of revision surgery were only reported in a few studies, and the use of different outcome tools made comparison difficult (►**Table 5**).[13,16,17,19–21]

Fischer et al reported on the outcomes of revision arthroplasty in 16 cases, with scores preoperatively and at 1 and 5 years postoperatively.[20] In addition to the disabilities of the

Table 2 A summary of the 14 studies including the primary procedure and revision procedure

Study	Primary procedures (no. of cases)	Total number of index cases	Revision procedures	Procedure method	Bone graft
Cooney et al (1984)[8]	Meuli—44	32	Wrist arthroplasty—29; revision for infection (staged fusion)—2; resection arthroplasty infection—1	Revision arthroplasty-Meuli, Swanson, Volz; revision arthrodesis—BG and external fixation	Autograft
Ferlic et al (1992)[9]	Swanson—7; Clayton-Verlic-Volz—4; Volz (cemented)—6; Biax (cemented)—2	16	Wrist arthroplasty—5; wrist arthrodesis—9; revision for infection (staged fusion)—2	Revision arthroplasty using Volz—5; revision arthrodesis - BG & Steinmann/Rush pins $\pm$ K-wires or staples	Contoured ICBG
Rettig and Beckenbaugh (1993)[10]	Swanson—7; Meuli (cemented)—2; Biax—2; Volz—2	13	Wrist arthroplasty	Biax TWA	–
Cobb and Beckenbaugh (1996)[11]	Biax—7; Volz—1; Swanson—1; Contra-lateral failed Biax—1	10	Wrist arthroplasty	Biax long-stemmed multipronged distal revision TWA	–
Beer and Turner (1997)[12]	Swanson—8; Meuli (cemented)—2; Volz (cemented)—1; Biax (cemented)—1.	12	Wrist arthrodesis	Revision arthrodesis—BG and Steinmann pin $\pm$ staples	Tricortical ICBG
Lorei et al (1997)[13]	Trispherical—8; Volz—1	9	Wrist arthroplasty—3; wrist arthrodesis—5; resection arthroplasty—1	Revision arthroplasty-Custom Trispherical TWA; revision arthrodesis—BG and Steinmann pin—2, Dorsal plate—3	ICBG—2; Allograft—3
Carlson and Simmons (1998)[14]	Swanson—5; Biax—6; Volz—1	12	Wrist arthrodesis	BG and Steinmann pin	ICBG—4; Allograft femoral head—7
Vogelin and Nagy (2003)[15]	Meuli I-III—13	14	Wrist arthroplasty—10; wrist arthrodesis—4; $\pm$ soft tissue reconstruction	Meuli	No detail
Talwalkar et al (2005)[16]	Biax—10	10	Wrist arthroplasty—5; wrist arthrodesis—3; resection arthroplasty—2	Revision arthroplasty-Biax; revision arthrodesis—BG Steinmann pin/dorsal plate	ICBG
Rizzo et al (2011)[17]	Silicone—3; Biax—12; Meuli—4; KMI—2;	21	Wrist arthrodesis	BG and Steinmann pin/wrist arthrodesis plate ($\pm$staples)	ICBG—6; Allograft contoured femoral head—9; Local autograft—3; Demineralize BG—3
Adams et al (2016)[18]	Swanson—1; Universal—8; Universal II—7; Biax—2; Clayton-Verlic-Volz—2	20	Wrist arthrodesis	BG and dorsal wrist plate	Allograft contoured femoral head
Reigstad et al (2017)[19]	Elos—5; Motec—6	11	Wrist arthroplasty—4; wrist arthrodesis—5; revision for infection (staged fusion)—2	Revision arthroplasty-Motec; revision arthrodesis-dorsal plate, customized peg	–
Fischer et al (2018)[20]	Swanson—5; Biax—7; Re-motion—3; Universal II—1	16	Wrist arthroplasty	Biax—6; Universal II—3; Re-motion—7	Supplementary: cement—6; Synthetic BG—9; femoral head allograft—1
Pinder et al (2018)[21]	Swanson—5; Biax—8; Universal II—5	18	Wrist arthroplasty	Biax—7; Universal II—11	Impaction BG—6; ICBG—1

Abbreviations: BG, bone graft; ICBG, iliac crest bone graft; KMI, Kinetikos Medical Incorporated; TWA, total wrist arthroplasty.

Arm, Shoulder and Hand (DASH) and Patient-rated Wrist Evaluation (PRWE) scores summarized in ►**Table 5** they also reported on the Canadian Occupational Performance Measure (before surgery, 3.6; 1 year, 4.8; and 5 year, 4.8) and satisfaction (before surgery, 2.7; 1 year, 5.6; and 5 year, 5.0). The improvement in all measures was significant only at the 1-year time point ($p < 0.05$) but worsened toward the 5-year time point. Talwalkar et al reported on revision arthroplasty with the Biaxial implant in five cases using the hospital for special surgery tool.[16] They observed a good outcome following revision surgery with patients scoring 72.5 (range: 63–80; 100 = excellent) on the outcome measure at an average follow-up of 36 months (range: 4–60). Pinder et al, reported on a cohort of 18 revision arthroplasty cases using various tools at an average follow-up of 10.4 years (range: 5.5–18.2).[21] They measured a QuickDASH score of 57

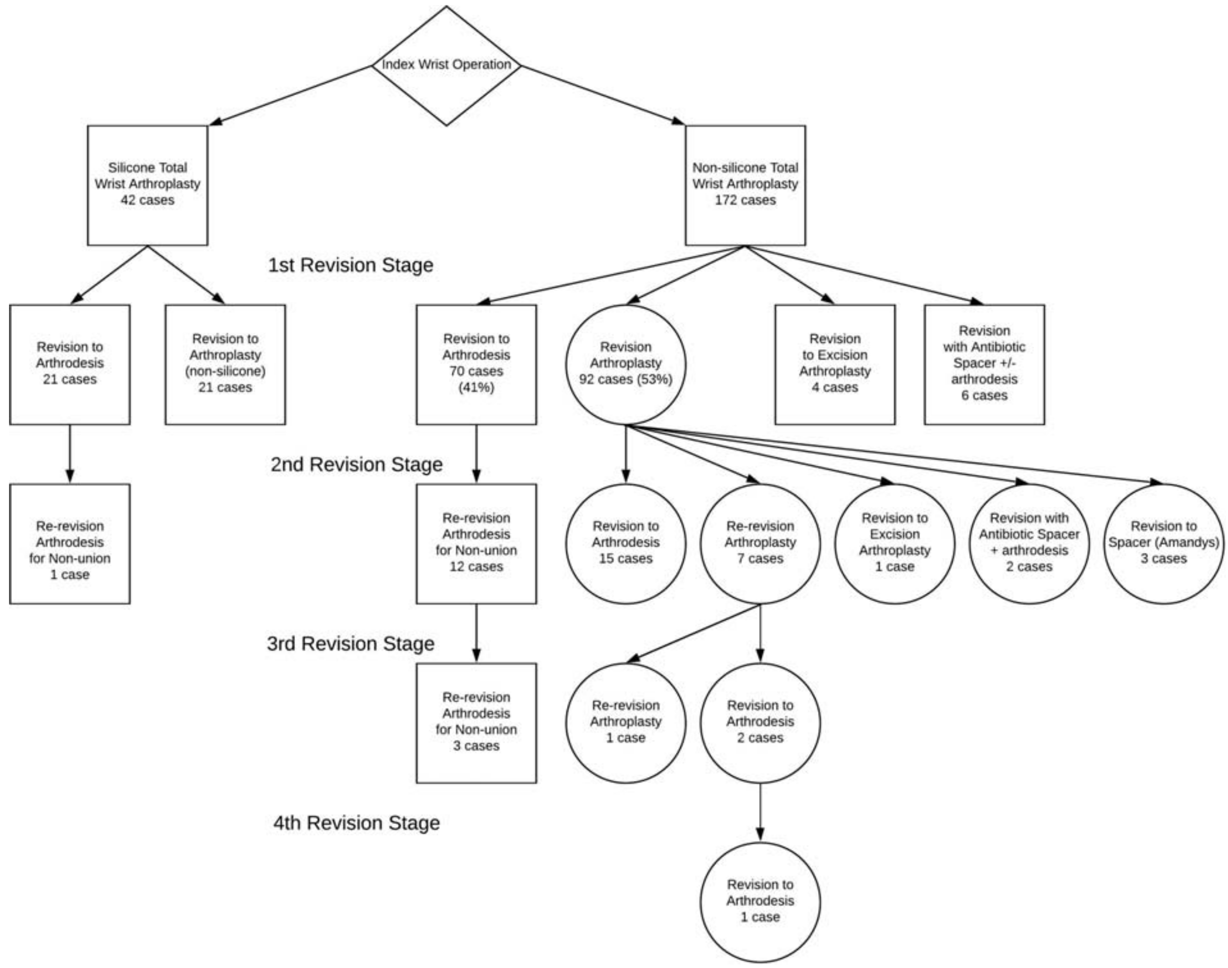

Fig. 2 Summary of the revision and re-revision procedures performed for the 214 cases included in this study.

Table 3 Summary of the different implants across the 14 studies

Implant	Total number
Meuli	65
Biax	58
Silicone	42
Universal II	13
Volz	12
Universal	10
Trispherical	8
Clayton-Verlic-Volz	6
Motec	6
Elos	5
Re-motion	3

(100 = poor), Patient Evaluation Measure (PEM) score of 49 (100 = poor), and PRWE score of 61 (100 = poor).[21]

The DASH score was also used by Rizzo et al in assessing the outcome of revision wrist arthrodesis for failed arthroplasty.[17] The overall DASH score was 33 (range: 11–59) measured at the most recent follow-up, which averaged 5.7 years (range: 2–21). Reigstad et al demonstrated similar

Table 4 Reason for total wrist arthroplasty failure

Pain	18
Loosening	88
Proximal	5
Distal	57
Polyethylene wear	1
Undefined	25
Instability	29
Fracture	
Silicone fracture	23
Implant fracture	7
Periprosthetic fracture	1
Infection	14
Other	
Attritional tendon failure	18
Stiffness	3
Silicone synovitis	1
Flexion deformity	1

Note: Data should be used as a guide only as this information was limited in some papers.

Table 5 A summary of the functional outcome scores

Study	Primary procedure (no. of cases)	Revision procedure	Functional measure
Lorei et al (1997)[13]	Trispherical - 8; Volz—1	Wrist arthroplasty—3; Wrist arthrodesis—5; Resection arthroplasty—1	Full return to all ADLs six of nine cases
Wrist arthrodesis functional outcomes			
Talwalkar et al (2005)[16]	Biax—10	Wrist arthroplasty—6; Wrist arthrodesis—3; Resection arthroplasty—2	HSS tool (100 = excellent): Arthrodesis—63.3 (range: 45–75); (Excision arthroplasty—92; [range: 84–100])
Rizzo et al (2011)[17]	Silicone—3; Biax—12; Meuli—4; KMI—2;	Wrist arthrodesis	DASH score (100 = poor): Overall = 33 (range: 11–59)
Reigstad et al (2017)[19]	Elos—5; Motec—6	Wrist arthrodesis	Mean follow-up 6.4 y (SD 1.9): QuickDASH score (100 = poor): Pre-op—54 (SD 21); post-op—32 (SD 20) ($p = 0.007$) PRWE score (100 = poor): Post-op—29 (SD 20)
Wrist arthroplasty functional outcomes			
Talwalkar et al (2005)[16]	Biax—10	Wrist arthroplasty—5; Wrist arthrodesis—3; Resection arthroplasty—2	HSS tool: Arthroplasty—72.5 (range: 63–80)
Fischer et al (2018)[20]	Swanson—5; Biax—7; Re-motion—3; Universal II—1	Wrist arthroplasty	DASH score: Pre-op—47; 1 y—29 ($p < 0.05$); 5 y—60 PRWE score: Pre-op—55; 1 y—24 ($p < 0.05$); 5 y37
Pinder et al (2018)[21]	Swanson—5; Biax—8; Universal II—5	Wrist arthroplasty	Mean follow-up 10.4 y (range: 5.5–18.2): QuickDASH score—57; PEM score—49 (100 = poor); PRWE score—61.

Abbreviations: ADL, activities of daily living; DASH, Disabilities of the Arm, Shoulder and Hand; KMI, Kinetikos Medical Incorporated; HSS, Hospital for Special Surgery; PEM, Patient Evaluation Measure; PRWE, Patient-rated Wrist Evaluation.
Note: Functional outcome was only reported in seven studies. The results have been separated into wrist arthrodesis outcomes and wrist arthroplasty outcomes.

outcomes following revision arthrodesis with the QuickDASH measure (Pre-op—54 [SD 21]; post-op—32 [SD 20], $p = 0.007$).[19]

Is There an Improvement in Secondary Outcome Measures Including Pain, Grip Strength, and Range of Motion?

Other reported outcome variables included grip strength and pain. Only marginal gains were seen in postoperative grip strength as reported in two studies performing revision arthroplasty. An increase from 8.3 kg (range: 0–14) to 9.1 kg (range: 1–22) was seen when using the Biaxial wrist as a revision system.[10] An improvement from 5 kg (range: 4–12) to 7 kg (range: 3–14) at 5 years with revision arthroplasty was reported by Fischer et al.[20] In contrast, the improvement in grip strength seen with revision wrist arthrodesis was more substantial in one study (12 kg [SD 11] to 23 kg [SD 15], $p = 0.026$).[19]

The postoperative pain scores are summarized in ►**Table 6**. In general, patients appeared to be in no pain or in mild pain postoperatively. The only studies providing pre- and postoperative comparisons were Reigstad et al and Fischer et al.[20] Reigstad et al, demonstrated a significant reduction in pain following revision wrist arthrodesis (5.7 [SD 3.0] to 2.2 [SD 2.2], $p = 0.001$).[19] Fischer et al, reported a nonsignificant improvement in activity-related pain from 5 (range: 1–8) to 0 (range: 0–3.5) at 5 years post-revision wrist arthroplasty.[20]

The range of motion following revision arthroplasty was reported in four studies (►**Table 7**). Fischer et al compared pre- and postoperative range of motion and found no significant improvement at 1 and 5 years.[20] In addition to the four studies listed in ►**Table 7**, Pinder et al observed an average flexion-extension arc of 26 degrees following revision arthroplasty.[21]

Patient-reported subjective outcome measures were only reported in five of the 12 studies representing a total of 56 patients.[10–12,14,17] The results demonstrated that 79% (44 patients) reported an excellent outcome, 18% (10 patients) reported a good outcome, and 3.6% (2 patients) reported either the same or a poor outcome.

What Are the Complications Associated with Revision of the Failed Total Wrist Arthroplasty?

There were 138 reported complications across the 14 studies (►**Table 8**). Roughly this equates to a 1:2 complication risk in performing revision surgery for wrist arthroplasty. The complications could be broadly divided into soft tissue issues such as tendon rupture, metalwork-related (e.g., pin migration, loosening) and graft site complications. Tendon

Table 6 A summary of the pre- and postoperative pain scores

Study	Revision procedures	Preoperative pain score (mean unless otherwise stated)	Postoperative pain score (mean unless otherwise stated)
Rettig and Beckenbaugh (1993)[10]	Wrist arthroplasty		No pain—8; mild—1; moderate—1
Cobb and Beckenbaugh (1996)[11]	Wrist arthroplasty		No pain—6; mild pain—2
Beer and Turner (1997)[12]	Wrist arthrodesis		Absent or mild—11
Lorei et al (1997)[13]	Wrist arthroplasty—3; wrist arthrodesis—5; resection arthroplasty—1		None—8; mild—1
Carlson and Simmons (1998)[14]	Wrist arthrodesis		No pain—10/10
Talwalkar et al (2005)[16]	Wrist arthroplasty—5; wrist arthrodesis—3; resection arthroplasty—2		Biax—3 (range: 0–5); fusion—3 (range: 0–5); excision—1 (range: 0–1)
Rizzo et al (2011)[17]	Wrist arthrodesis		2.6 (range: 0–7)
Adams et al (2016)[18]	Wrist arthrodesis		Absent or mild—18
Reigstad et al (2017)[19]	Wrist arthrodesis	5.7 (SD 3.0)	2.2 (SD 2.2) $p = 0.001$
Fischer et al (2018)[20]	Wrist arthroplasty	5 (range: 1–8) activity; 0 (range: 0–3) rest[a]	5 y: 0 (range: 0–3.5) activity; 0 (0) rest[a]
Pinder et al (2018)[21]	Wrist arthroplasty		2.9

Abbreviation: SD, standard deviation.
Note: All studies utilized the visual analogue scale for reporting. Scale 0–10 (worse pain).
[a]Data presented as median.

Table 7 A summary of the range of motion after revision total wrist arthroplasty

Study	Flexion	Extension	Pronation	Supination	Radial deviation	Ulna deviation
Rettig and Beckenbaugh (1993)[10]	19	36			6	15
Cobb and Beckenbaugh (1996)[11]	17 (5–14)	39 (5–65)	77 (65–90)	78 (65–85)	12 (5–20)	18 (5–40)
Talwalkar et al (2005)[16]	31 (10–60)	19 (0–45)	90	50 (0–90)	7 (0–15)	12 (0–25)
Fischer et al (2018)[20]	25 (18–43)	30 (20–40)	85 (78–88)	85 (83–90)	5 (−10–13)	15 (7–28)

Note: All measures in degrees. Range given in parentheses.

ruptures were a relatively common complication following revision surgery. Ruptures of both extensor pollicis longus and flexor pollicis longus were observed. Median nerve compromise requiring decompression occurred in 6.4% of the cases and included a median nerve attrition from a palmarly dislocated prosthesis requiring microsurgical repair.[15] Arthrodesis was commonly achieved using either Steinmann pins or Rush pins and so pin migration and perforation was a common complication occurring in 21.8% of the cases. Loosening and subsidence of the revision arthroplasty was a common problem (18.2%).

What Are the Survival Profiles of the Different Revision Strategies?

Failure of the revision procedure leading to a re-operation occurred in 35 of the 162 nonsilicone arthroplasty cases, suggesting a re-revision rate of 21.6% (►**Fig. 2**).[8–12,14,15,17–21] The re-revision rate following a revision arthrodesis was 21.4% (15 of 70 cases) compared with the rate if a revision arthroplasty had been performed of 34.8% (32 of 92 cases) of the cases. However, a relatively high nonunion rate of 17.5% (22 cases) with arthrodesis was also observed across all the studies in this review.

There were a further five described failures of the re-revision procedures requiring further surgery (►**Fig. 2**). These procedures included revision arthrodesis for arthrodesis nonunion or for salvage of the failed revised wrist arthroplasty. In a further case, a custom-made implant was used to revise a failed revision wrist arthroplasty.[10] Distal loosening was the common reason for failure of the revision implants.

The cumulative 5-year revision implant survival was reported as 83% (18 cases) by Pinder et al and 74% (16 cases) by Fischer et al.[20,21] Pinder et al observed radiological

Table 8 A summary of the complications observed following revision surgery

Complication associated with revision procedure	% (No. of complications)
All procedure analysis (264 index cases)	
Soft tissue complications	
Median nerve compromise	6.4 (17)
Superficial infection	0.4 (1)
Deep infection	2.7 (7)
Tendon rupture	6.1 (16)
Revision arthrodesis (126 index cases)	
Arthrodesis nonunion	17.5 (22)
Pseudoarthrodesis	5.6 (7)
Metalwork complications	
Pin migration (55 index cases)	21.8 (12)
Prominence	4.0 (5)
Metalwork failure	4.0 (5)
Graft site complications (53 index autograft cases)	11.3 (6)
Revision arthroplasty (121 index cases)	
Metalwork complications	
Loosening	18.2 (22)
Dislocation	6.6 (8)
Fracture	8.3 (10)

Note: All procedure analysis as a proportion of all index procedures including re-revisions (no. = 264). Revision arthrodesis and arthroplasty analysis performed as a proportion of the respective procedure as indicated in the table (i.e., pin arthrodesis—55 cases).

evidence of gross loosening in 60% of carpal components and 50% of radial components at mean follow-up of 6.7 years (range: 0.6–18).[21] In Rettig and Beckenbaugh's study, three of 13 revision Biaxial wrist replacements were revised at a mean follow-up of 31 months (range: 12–58) providing an implant survival of 77%.[10] Cobb and Beckenbaugh had an implant survival of 80% at a mean follow-up of 3.8 years (range: 3–4.8) using a custom long stemmed Biaxial revision implant.[11]

Discussion

Salvage of the failed total wrist arthroplasty is challenging. As previously described the commonly performed salvage operations are conversion to a wrist arthrodesis, a revision arthroplasty, and finally excision arthroplasty. A revision arthroplasty is contraindicated if there is significant bone loss, major soft tissue compromise, or infection. There is a high failure rate of the revision procedure as can be seen from this review, and salvage to a functional wrist often requires multiple operations including soft tissue procedures. Of the failed nonsilicone primary arthroplasty cases considered by the 14 studies included, 21.6% of the cases (35/162) required at least one further procedure (re-revision arthroplasty or further fusion) during the follow-up periods considered (range: 2 months–21 years).

From the results presented, arthrodesis appears to be a more predictable method to salvage the failed implant. In this study, a revision arthrodesis had a lower re-revision rate (21.4%; 15 of 70 cases) compared with the re-revision rate for a revision arthroplasty (34.8%; 32 of 92 cases). However, conversion to an arthrodesis still poses significant challenges including managing bone loss and achieving bony fusion. Various techniques have been used to achieve these goals with differing success rates. Adams et al was able to achieve high fusion rates with their technique using contoured femoral head allograft and a dorsal locking plate in 19 of 20 cases (a technique based on a previous study by Carlson and Simmons).[14,18] The other bone graft option was iliac crest bone graft, although a large graft size is required and this may be associated with harvest site morbidity, such as iliac wing fracture.[12] Use of allograft circumvents some of these issues. The use of Steinmann or Rush pins instead of dorsal plating has also been involved to achieve fusion but a high rate of pin migration and perforation has been seen.[11,12,14,17] Other techniques exist to address extensive bone stock defects; for example, in our practice we have used free fibular flaps in salvage procedures where we have encountered extensive soft tissue and bony defects, such as in the presence of an infected arthroplasty, and have found it to be a good although more invasive and technically challenging alternative to allograft and nonvascularized autograft bone.

Although data was limited, there was a trend for better functional outcomes following arthrodesis compared with revision arthroplasty. A more direct comparison could be made between the studies on revision arthrodesis by Rizzo et al and Reigstad et al,[17,19] and studies by Fischer et al and Pinder et al reporting on revision arthroplasty.[20,21] Rizzo et al reported DASH scores of 33 (range 11–59) after arthrodesis similar to the QuickDASH scores of 32 (SD 20) reported by Reigstad et al .[17,19] Fischer et al reported DASH scores of 60, similar to the QuickDASH scores of 57 reported by Pinder et al.[20,21]

A variety of different implants were used if revision arthroplasty was chosen to manage the failed wrist replacement. In a recent case review by Fischer et al, wrist arthroplasty was seen as a valid option especially if motion preservation was desired. However, the authors state that the outcome was less predictable and a high re-operation rate of 25% was noted.[20]

Previous studies have demonstrated a shorter survival time for revision wrist arthroplasty. Cobb and Beckenbaugh had an 80% implant survival at 3.8 years using a revision Biaxial system.[11] More recent data by Pinder et al and Fischer et al, performing revision surgery using contemporary generations of implants, suggest more favorable survival. Cumulative 5-year implant survival was reported as 83 and 74%, respectively.[20,21] Subsequent loosening following a revision arthroplasty, especially of the distal component has been a common issue and is typically managed with conversion to an arthrodesis; in the cases considered here, 15 of the 28 failed revision arthroplasties were initially revised to arthrodesis, with two of the seven cases that were re-revised to wrist arthroplasties ultimately being fused as well (►Fig. 2). Additional soft tissue procedures are also a common finding, either to achieve a balanced wrist, to manage tendon ruptures, or for median nerve compromise.[9,15] Vogelin and Nagy described as many as 26 additional soft tissue operations in their case series of 13 patients.[15]

This review demonstrates some of the issues surrounding salvage of the failed total wrist arthroplasty. The failure rate of revision procedures is relatively high. In this systematic review, a 21.6% re-revision rate of the salvage procedure was observed in the nonsilicone arthroplasty procedures alone. Various techniques have been employed over the last few decades with varying success. The review highlights the variability in outcomes and success rates of revision surgery for the failing wrist arthroplasty. Furthermore, revision surgery is technically challenging and careful preoperative planning is essential. Patients must be well informed before embarking on wrist replacement surgery. However, there is evidence to support improved performance and survival of more modern wrist arthroplasty systems.[7] It may well be that a reduction in complications in arthroplasty surgery could be achieved if these procedures are performed by fewer surgeons undertaking higher numbers of index operations.[28]

This review considers a relatively low number of case series with limited follow-up periods, and as such, the findings are subject to potential reporting and follow-up biases. Given the high reported complication and revision rates and the relatively low volume of procedures, we think there is a strong argument for the adoption of universal post-marketing surveillance of wrist arthroplasty components, as could be achieved by inclusion of implantations in national registries, to monitor performance, and provide feedback to both patients and surgeons.

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Conflict of Interest
None declared.

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Appendix 1: OVID Medline search strategy

1. exp Arthritis/
2. arthri*.ti,ab.
3. Osteoarthritis/
4. osteoarthr*.ti,ab.
5. $arthri*.ti,ab.
6. (inflam* adj3 joint*).ti,ab.
7. 1 or 2 or 3 or 4 or 5 or 6
8. Wrist/
9. Wrist Injuries/
10. Wrist Joint/
11. wrist*.ti,ab.
12. exp Carpal Bones/
13. carpal.ti,ab.
14. scaphoid*.ti,ab.
15. lunate.ti,ab.
16. triquetrum.ti,ab.
17. pisiform.ti,ab.
18. trapezium.ti,ab.
19. trapezoid*.ti,ab.
20. capitate.ti,ab.
21. hamate.ti,ab.
22. 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21
23. 7 and 22
24. arthroplasty/ or arthroplasty, replacement/
25. replac*.ti,ab.
26. exp "Prostheses and Implants"/
27. Joint Prosthesis/
28. prosthe*.ti,ab.
29. 24 or 25 or 26 or 27 or 28
30. Arthrodesis/
31. arthrodes*.ti,ab.
32. fusion*.ti,ab.
33. 30 or 31 or 32
34. 23 and 29 and 33

Appendix 2: OVID EMBASE search strategy

1. exp arthropathy/
2. exp arthritis/
3. arthr*.ti,ab.
4. exp osteoarthritis/
5. osteoarthr*.ti,ab.
6. $arthr*.ti,ab.
7. exp wrist injury/
8. 1 or 2 or 3 or 4 or 5 or 6 or 7
9. exp wrist/
10. wrist.ti,ab.
11. exp carpal bone/
12. carpal.ti,ab.
13. scaphoid*.ti,ab.
14. lunate.ti,ab.
15. triquetrum.ti,ab.
16. pisiform.ti,ab.
17. trapezium.ti,ab.
18. trapezoid*.ti,ab.
19. capitate.ti,ab.
20. hamate.ti,ab.
21. 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20
22. 8 and 21
23. exp arthroplasty/
24. arthroplasty.ti,ab.
25. exp joint prosthesis/
26. prosthe*.ti,ab.
27. replac*.ti,ab.
28. 23 or 24 or 25 or 26 or 27
29. arthrodesis/
30. arthrodes*.ti,ab.
31. fusion.ti,ab.
32. 29 or 30 or 31
33. 22 and 28 and 32

Appendix 3: CINAHL search strategy

1. exp *ARTHRITIS/
2. (arthr*).ti,ab
3. exp *OSTEOARTHRITIS/
4. (osteoarthr*).ti,ab
5. (inflam* ADJ3 joint).ti,ab
6. *"WRIST INJURIES"/
7. exp *WRIST/
8. exp *"WRIST JOINT"/
9. "CARPAL BONES"/
10. (carpal).ti,ab
11. exp *"ARTHROPLASTY, REPLACEMENT"/
12. (replac*).ti,ab
13. exp *"ORTHOPEDIC PROSTHESIS"/
14. (prosthe*).ti,ab
15. exp *ARTHRODESIS/
16. (arthrodes*).ti,ab
17. (fusion).ti,ab
18. (1 OR 2 OR 3 OR 4 OR 5 OR 8)
19. (6 OR 7 OR 9 OR 10)
20. (11 OR 12 OR 13 OR 14)
21. (15 OR 16 OR 17)
22. (18 AND 19 AND 20 AND 21)

Appendix 4: BNI search strategy

1. exp "ARTHRITIS AND RHEUMATISM"/
2. (arthri*).ti,ab
3. (osteoarthr*).ti,ab
4. exp "JOINT DISORDERS"/
5. (wrist).ti,ab
6. (arthroplasty).ti,ab
7. (replacement).ti,ab
8. (prosthesis).ti,ab
9. (arthrodesis).ti,ab
10. (arthrodes*).ti,ab
11. (fusion).ti,ab
12. (1 OR 2 OR 3 OR 5)
13. (6 OR 7 OR 8)
14. (9 OR 10 OR 11)
15. (4 AND 12 AND 13 AND 14)